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# STARVATION OF THE EARLY INSTARS OF THE PALE WESTERN CUTWORM, *AGROTIS ORTHOGONIA* MORR., AND ITS USE IN THE CONTROL OF THIS PEST*

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Each year since 1911 the pale western cutworm, *Agrotis orthogonia* Morr., has taken a toll of the grain crops in some part of the Canadian prairies. The extent of the outbreak has varied from small, isolated areas of infestation to general outbreaks covering over 150,000 square miles. Until 1936 the only practical method of controlling this cutworm was the use of definite cultural practices designed to prevent the moths from ovipositing in certain fields during August and early September. Field history studies and spring cultural experiments have produced much conflicting evidence regarding a possible spring cultural control for this insect, and yet field observations have shown that there is some combination of circumstances in the spring which does produce an effective control.

Many attempts have been made to determine the factors responsible for this control. Field history records have shown that 21 per cent of the acreage which was spring-ploughed was destroyed by pale western cutworm. Experiments on burying eggs and larvae have indicated that such treatment would not materially reduce the numbers. This was further corroborated when it was found that the eggs usually begin to hatch soon after the frost is out of the top two inches of the soil, so that most of the early-spring ploughing would actually bury first-instar larvae. Cook† suggests that early-spring ploughing provides an excellent control because it turns the young larvae down several inches into cold soil where the temperature is about 10° C. At this temperature the larvae are sluggish, and being unable to secure food, eventually starve to death before temperatures sufficiently high to induce activity penetrate to that depth. An experiment conducted at Lethbridge during the winter of 1929-30 showed that eggs would hatch at a temperature of 6° C. and that the larvæ could live for several weeks at this temperature without food. Such larvae showed no ill effects when placed at a higher temperature, and when fed proceeded to develop normally. The fact that first-instar larvae can live for long periods without food has since been amply demonstrated in the laboratory and in the field.

During the past ten years, experiments in starving and underfeeding all stages of larvae have shown that the length of time the larvae can go without food is roughly proportional to their size and age, with the exception of the newly hatched first-instar larvae. Fields have often been observed in which every vestige of vegetation has been destroyed, and in several instances the older larvae have been found feeding on wet, well-rotted straw or stubble. Experiments indicate that this is not a suitable food, and that it will not suffice to bring the larvae to maturity. In most cases a scanty food supply is furnished by newly sprouting weed seeds, so that actual starvation resulting from the complete destruction of a crop is hardly probable.

In 1936 an experiment was conducted to determine what percentage of the larger larvae might be starved in the field if the crop on which they were

* Read before a joint meeting of the American Association of Economic Entomologists, the Entomological Society of America, and the Entomological Society of Ontario, A. A. A. S., at Ottawa, Ontario, June 30, 1938.

† W. C. Cook, Montana Experiment Station Bulletin 255, pp. 61-62.

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feeding was destroyed by cultivation. At the time the crop was cultivated, careful population counts showed that an average of 23 third-instar larvae per square yard were present in the field. Subsequent population counts showed a steady drop in the numbers of larvae present but also a steady development of these larvae. At the end of 34 days the population was 1.6 sixth-instar larvae per square yard. While this population dropped approximately 93 per cent by the time the larvae were mature, the population in an adjacent field where food was abundant dropped 61 per cent. Since the same predators and parasites were present in both fields, it is quite probable that starvation accounted for the difference in the decrease in population, or 32 per cent.

During the winter of 1935-36, experiments were started in a greenhouse to determine what factors of spring cultivation might be providing the apparent control of the pale western cutworm. The first series of experiments consisted of burying newly hatched and second-instar cutworms in the soil at different depths in flats, (a) where no wheat was planted, (b) at the same time the wheat was planted, and (c) after the wheat was above ground. The results of these experiments were somewhat conflicting, both with each other and with field observations. They did indicate that first- and second-instar larvae when buried three and four inches caused less injury to the wheat than when buried at one or two inches.

This series of experiments was followed by a second, in which field conditions were simulated. All flats used in this series of experiments were first seeded with mixed weed seed. When the weeds were about an inch high, freshly hatched and second-instar larvae were sprinkled on the surface of the soil in the flats. After three or four days this soil was cultivated at different depths with hand implements to destroy the weed growth, and then seeded either immediately or seven days after the cultivation. One hundred kernels of wheat were seeded in each flat. As the wheat came up, careful records were kept of the injury to the plants, and the seeds that did not come up were examined for signs of injury to the sprouts or seed. The wheat came through the ground three days after all weeds had wilted. This meant that larvae on the surface of the soil were subjected to three days of starvation when the wheat was planted immediately after the weeds were destroyed, and to ten days of starvation when the wheat was planted seven days after the weeds were destroyed.

The results of these experiments showed that, when the wheat was seeded seven days after the weeds were cultivated out of the flats, the damage to the wheat was considerably less than when the wheat was seeded immediately. This was found to be true with both first- and second-instar larvae, although the flats originally containing larvae in the first-instar suffered a greater crop damage than did those containing second-instar larvae.

Another experiment was conducted to determine the effect of temperature and humidity on the starvation of first-instar larvae. Series of larvae were kept at the following constant temperatures: 29° C., 21° C., 13° C., 6° C. and 24° C. and 80 per cent relative humidity. In each of these conditions there were three series of first-instar larvae. The first series contained larvae which were fed constantly, the larvae in the second were fed 5 days and then starved, and those in the third were starved from the time they hatched from the egg.

The results of this study indicated that unless food is constantly available, first-instar larvae will not survive a prolonged temperature of 29° C., nor will they survive, even when fed, at a prolonged exposure at 24° C. and 80 per cent relative humidity. This is probably as much a result of the humidity as of the temperature, since the average relative humidity in the Canadian prairies is very low. At temperatures of from 6° C. to 21° C. the average length of life of first-instar larvae which were fed 5 days and then starved was from 9 to 3 days, the longer life occurring at the lower temperature. The average length of life of larvae which had never fed was from 13 to 5 days. This corroborates the field observations that larvae hatching late in March or early in

April can survive until food is available. These results also showed that first-instar larvae can be destroyed by a few days' starvation, which occurs after they have taken food and started some development.

The experiments, coupled with the previously known fact that first- and second-instar cutworms do most of their feeding on the portions of plants above ground, suggested that spring cultural practices might be so timed as to produce control in the field by starvation. This control would first require vegetation present on which the larvae could feed. If this vegetation were then destroyed and seeding delayed a sufficient length of time, the larvae might starve to death.

A detailed experiment was planned to provide a series of plots with periods of from 1 to 10 days between cultivation and seeding, but before it could be carried out a 640-acre field was located in which a similar series of conditions already existed. The manner in which the field was cultivated and seeded provided 12 plots of about 53 acres each, with 2-, 3-, 4-, 5-, 6-, 11-, 12- and 13-day intervals between the two operations. There was a delay of 4 days between cultivation and seeding on three plots, and 3 days, 5 days and 11 days on two plots each. Plots showing the other periods of delays were not duplicated. Careful examinations were made to determine the percentage of the plants on each plot which showed some injury by first- and second-instar larvae, and later in the season estimates were made of the crop loss on each plot.

Before the larvae had reached the fifth-instar, the crop in the plots with 2-, 3- and 4-day intervals between cultivation and seeding were so severely damaged that the land was cultivated and prepared for reseeding. The crop in the plots with 5- and 6-day intervals between cultivation and seeding was slightly damaged, but was left to mature, and the rest of the plots suffered no loss.

When the results first began to be evident early in the season, a second field of 640 acres was located in which the first- and second-instar larvae were rapidly destroying the volunteer wheat and weeds. The field was being cultivated in preparation for seeding, and the operator was requested not to seed the field for 10 days after the cultivation was completed. Cultivation was completed May 9, and seeding was started on May 19. A close examination of this field showed less than 1 per cent of the plants injured.

In 1937, several farmers agreed to try this control. Fields in the immediate neighborhood belonging to farmers who did not wish to try it were used as checks. All fields selected were examined to make sure that first-instar cutworms were present. There were 39 fields, totalling 9,615 acres, in the control series, and 34 fields, totalling 7,487 acres, in the check series. The results of this work are shown in the following table:—

| Series | No. of fields | Total acres | Total fields showing loss | Acres destroyed | Percentage loss |
|---|---|---|---|---|---|
| Control | 39 | 9,615 | 5 | 141 | 1.46 |
| Check | 34 | 7,487 | 34 | 3,784 | 50.50 |

The most severe loss in any of the control fields was 10 per cent, and the lowest loss in any of the check fields was 10 per cent. Of the losses in the control fields, the most serious were the result of poor cultivation, which did not completely destroy the surface vegetation. In one instance, cutworms were carried into the field with drifting soil after the crop had come up, and in another instance soil drifting prevented early vegetation from getting started and the cultivation was done before the young cutworms had begun to feed.

Several of the check fields were cultivated before any vegetation was present, and though a delay occurred between the cultivation and seeding, it served only to prolong the normal pre-development starvation period of the

young larvae. Most of the check fields were cultivated and seeded in one operation, while a few contained fall wheat or fall rye which was seeded during the period of the moth flight in August, 1936, and no control measures were used.

One field in particular provided an example of the effectiveness of this control practice. This field had been seeded to fall rye during the peak of the moth flight in 1936. The rye made a strong growth in the spring of 1937, and by April 12 it was three inches high. At this time it was found that the leaves were being rapidly destroyed by first-instar larvae. From 4 to 10 larvae could be found around each plant. The field was cultivated during the next two days, and a second cultivation which completely destroyed all of the rye followed a week later. Ten days after the second cultivation was completed the field was seeded to spring wheat. This crop was not damaged by cutworms, nor could larvae be found in the field after the wheat came up.

During the spring season of 1938, the starvation control was widely adopted in Southern Alberta. The season was late, and the precipitation in May was above the average. The frequent rains made the destruction of weed growth very difficult. In spite of this the losses by June 1 were negligible, and many fields which were originally severely infested with first-instar cutworms were showing no losses.

The general results of the starvation control work have been most satisfactory. In addition, the fact that young cutworms can be starved in the field has provided a satisfactory explanation of the peculiar conditions of crop losses that have been observed in portions of fields in the past. It is quite probable that this also explains the great reduction in cutworm populations that has been observed in some of the severe drought years. In such seasons the vegetation has started in the early spring, only to be completely destroyed by dry weather. Under these conditions the lack of food is accompanied by high temperatures, which, according to the experiments tend to destroy the young larvae in less time than would be the case if the temperatures were lower.

There has been some objection to the starvation method of control. The general impression seems to be that it will make the crops too late. The average date of seeding in 1937 was April 30, while the average date of seeding the control fields was May 15. The majority of these fields could have been seeded by May 8 or 10, but a few farmers delayed their seeding longer than was necessary. Some of the farmers who seed large acreages object to the necessity of going over the fields twice instead of cultivating and seeding in one operation. In spite of this objection, many of this type of farmer who used the control in 1937 are so enthusiastic over the excellent weed control which they secured by the extra cultivation that they will probably adopt the starvation control as a general practice whether cutworms are present or not.

## SUMMARY

The pale western cutworm, *Agrotis orthogonia* Morr., has been a serious pest of wheat on the Canadian Prairies since 1911. Repeated observations and field history studies have shown that effective control of this insect was produced in the field by some combination of factors, cultural or otherwise.

Attempts to starve the larvae of the pale western cutworm have shown that newly hatched larvae will live for several weeks in the field without food. After the second-instar has been reached the length of time the larvae of all ages can go without food is roughly proportional to their size and age.

Recent experiments have shown that newly hatched larvae can live without food for varying periods of time, depending on the temperature, but that after feeding has started, removal of the food supply results in starvation. The length of time the first-instar larvae can exist without food is longer at the lower temperatures in either case.

First- and second-instar larvae feed largely on the portions of plants

above the soil surface, and feeding commences as soon as green vegetation appears. Starvation control was considered possible by waiting for weed and volunteer growth to get started and then destroying this growth. This was first tried experimentally in the greenhouse in the winter of 1935-1936, and the results indicated that seeding a crop as soon as the cultivation was done did not produce satisfactory results, but if seeding was withheld for a few days the larvae were reduced in numbers and no damage to the crop resulted. Field experiments in 1936 corroborated this and indicated that seeding should be delayed more than six days but less than eleven days, if a complete control was to be secured.

Extensive field demonstrations in 1937 and 1938 and a study of field history records collected over the past fifteen years have further corroborated the previous results. The "starvation" control has been shown to be practical on both large and small fields. It does not delay the seeding of the crop sufficiently to endanger the quality and quantity of grain secured, and it provides an excellent weed control.

## BOOK NOTICE

Handbook of the Mosquitoes of North America (Second Edition), by Robert Matheson, Comstock Publishing Company, Ithaca, N. Y.; VIII plus 314 pages, 33 plates (frontispiece and 42 figs.) 1944. Price $4.00.

This handbook deals with the anatomy and biology of mosquitoes; their study and identification; how they carry disease, and how to control them. The first edition was published fifteen years ago and proved to be an exceptionally useful and usable textbook greatly valued by entomologists and other workers concerned with the study of this important and fascinating group of insects. It has been a source of information and inspiration to large numbers of students, many of whom are now putting their knowledge of mosquitoes to good use in the service of their fellow men, in dealing with the problems of mosquito-borne diseases on this continent and along the far-flung battle-fronts of the world.

The second edition of the handbook embodies the valuable features of its predecessor, but the text has been completely revised and amplified to bring it up to date. It appears at a time when the importance of mosquitoes as enemies of mankind is more widely appreciated by the general public than ever before, and even in these northern latitudes where mosquitoes are more generally regarded as troublesome pests than as carriers of disease, interest in their study and control has been greatly stimulated. Like its predecessor, the second edition is comprehensive but concise, lucidly written and effectively illustrated. The keys to genera and species have been rewritten and much improved, and for the most part are simple and clear, and eminently well suited to their purpose, namely, the rapid and accurate identification of the species. A new and useful feature is a section dealing with the sub-family Chaoborinae. The value of the handbook is enhanced by a more extended bibliography than was contained in the first edition. It is noted with satisfaction that the names of genera and species in the index are accompanied by the authors' names, a small point, perhaps, but a useful and time-saving one. Professor Matheson is to be congratulated on producing such an excellent and timely revision of his valuable book. He has performed a great public service.

C. R. Twinn.

# RESULTS FROM AN EXAMINATION OF GEOMETRID TYPES IN THE CAMBRIDGE MUSEUM OF COMPARATIVE ZOOLOGY*

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During a recent visit to the Museum of Comparative Zoology at Cambridge, Mass., undertaken primarily for the purpose of studying Chambers' Coleophorid types, I naturally took advantage of the opportunity to examine the numerous types of Geometridae incorporated from the Packard, Swett and Cassino collections. In consequence I was enabled to clear up a number of points which had been worrying me for some time and in the following notes I offer the main results of such studies.

## STERRHINAE

*Euacidalia chockolatella* Cass. The unique holotype looks superficially much like a dark specimen of *griseata* Cass. The genitalic slide, however, shows a simple uncus and a gnathos and the proper position of the species is rather doubtful.

*Euacidalia nigridaria* Cass. No types of this species could be found; placement remains doubtful.

*Euacidalia benubia* Cass. The holotype male is labelled 'Mar.' not 'Jan.', as given in the original description; also the statement 'palpi long, dark, upturned' does not apply, these being quite short and the normal size for the group. The color given as 'tawny is misleading, as the wings are a deep smoky-gray with maculation quite obscure but somewhat after the *marceata* type. An Allotype female is labelled but not mentioned in the original description; this shows a single pair of spurs on the hind tibiae, the male having an aborted hind-leg; the primaries show a single areole. The genitalia slides are very crushed but show a hood-like uncus, slightly bifid apically, a moderately well-developed gnathos, and a long narrow clasper with weak sacculus, terminating in a small spine near the truncate apex of the clasper; the aedeagus is extraordinarily long, terminates in a thin, fine spine and has a somewhat bulbous base. The whole organ—as far as could be discerned—seems practically identical with that of a specimen in our collection from Lakehurst, N.J., sent us as *violacearia* Wlk. It may readily be that one of Hulst's names included in the synonymy may apply to the species under discussion but our material is too scanty and my knowledge of the type material so imperfect that no decision can be made at the present time.

*Acidalia oliveata* Cass. The Holotype from McCreary, Man., is nothing but the ordinary prairie form of *inductata* Gn. in which the color of the wings is somewhat darker than that of eastern specimens; the color given in the original description as 'olive-green' is most misleading as is also the size, 42 mm.'. *Oliveata* should be sunk to *delicata* Cass. – the Type of which, incidentally, could not be found—and this latter name can be used, if desired, for a doubtful prairie race of *inductata*.

*Acidalia marceata* Cass. In the original description the antennae are described as 'filiform, not ciliate'. Neither in the Holotype nor in any of the paratypes is this the case, the male antennae being well ciliated. The species should probably be transferred to *Metasiopsis* as a double areole is present on the forewing.

## LARENTIINAE

### Genus **Eupithecia**

I was glad to find that, in the main, my notes on the synonymy of the Cassino species, appearing in various papers in the Canadian Entomologist, were correct. A few additional notes and some corrections are herewith offered.

* Contribution No. 2331, Division of Entomology, Science Service, Department of Agriculture, Ottawa.

*E. californiata* Gump. The name was proposed for three male Californian specimens collected by Behrens and noted by Packard under *miserulata* in the Monograph as somewhat different; these specimens had been picked out by Swett and are all in frightfully rubbed condition and without abdomens. The specimen marked 'Holotype' has simply a printed label 'California'; another cotype has the same type of printed label with the addition of 'Behrens' in writing, and is a female, not a male; a second 'cotype' has a written label 'Cal. Behrens' and is possibly not the same species as the other two. Accurate identification was impossible but as far as could be told the male holotype is a specimen of *rotundopuncta* Pack. Accepting this as correct, *californiata* can be sunk as a synonym of Packard's species and another troublesome name satisfactorily accounted for.

*E. ornata* Hlst. This proves to be a good species and not, as I quite erroneously suggested, the female sex of *edna* (1944, Can. Ent., LXXVI, 51). The Cassino collection was found to contain both sexes of both *ornata* and *edna* and I was able to obtain material for genitalic dissection. The male, which is quite similar in maculation to the female, is without hair-pencil at the base of the clasper and, in consequence, the species will fall into the *palpata* section and should be placed following *albimontanata*. The whole male genitalic organ is very close to my figure of *carolata* (op. *cit.* fig. 1); the female organ was figured as *edna* (fig. 8). It should be noted that the palpi are decidedly longer and more blade-like than those of *edna*, as stated by Hulst in the original description; the ciliations of the male antennae are moderately long; the figure in the 'Contributions (Vol. I, 4, Pl. XIV, fig. 14) gives a very good idea of the species.

*E. monacheata* C. & S. This species, which heretofore was entirely unknown to me, was represented in the collection by the female Allotype (without abdomen) from Monachee Meadows, Calif. and a female Paratype from Stockton, Utah. It most definitely belongs in the *palpata* group and is very closely allied to *ornata*, being however much larger and paler and with somewhat shorter palpi. The name should be restricted to the Monachee Meadows material as the specimen from Utah is considerably smaller and may prove to be something different. Based on my notes I was able to place a female from Inyo Co., Calif. as belonging to this species; a slide of the genitalia showed that they were practically undistinguishable from those of *ornata*. I further consider that the male specimen from Charleston Mts., Nevada, on which I based the name *carolata*, agrees with my Inyo Co. female and that *carolata* will fall into the synonymy of *monacheata*, which may, when more material can be studied, prove to be merely a race of *ornata*.

*E. edna* Hlst. The female of this species corresponds in maculation with the male and agrees excellently with the figure in the 'Contributions' (*op. cit.*, Pl. XIV, fig. 3), the sex of which was apparently correctly given. As might be expected the female genitalia are allied to those of *owenata* McD. (*op. cit.* fig. 9); the bursa is, however, less oval, showing an incipient foot jutting out to the right, the neck is narrower and longer and quite heavily striate, the blind-sac is situated dorsally with a projection to the left and the ductus seminalis arises from the upper ventral section of the neck, opposite the blind-sac, and curves backward and downward much as in *owenata*.

*E. joymakeata* Cass. My notes on this name (1941, Can. Ent., LXXIII, 192) were more or less substantiated by an examination of the type series. It was found, however, that the Holotype male had the head of a female – belonging to another species with quite long palpi – glued on; the abdomen was also missing but no slide number attached to the specimen. In other respects the holotype agreed with the balance of the type series, the males of which showed the short palpi and strongly ciliate antennae characteristic of *sierrae* Hlst. The holotype specimen showed a decidedly purple-brown color on primaries and was rather more strongly marked than most of the series but my reference as a dubious race of *sierrae* is correct.

*E. alpinata* Cass. In my description of the closely allied *prostrata* (1938, Can. Ent., LXX, 238/40) I called attention to the fact that I was unable to separate the males of the two species satisfactorily on superficial characters, and that, while the Allotype female of *alpinata* showed characters in the ovipositor,—as figured by me (Pl. XX, fig. 2a) — it would be necessary to make a slide of the genitalia of Cassino's male holotype to discover its identity. This I have now done and find that my male of *prostrata* (fig. 3a) agrees with what Cassino considered as his male of *alpinata*; as this is just as likely to be correct (with our present knowledge) as my original idea, I am accepting Cassino's sex-association and would therefore list *prostrata* ♂ (*nec* ♀) as a synonym of *alpinata*, transfering my so-called *alpinata* males to *prostrata*, my female holotype holding the specific name. As already pointed out Cassino's type series of *alpinata* contained both forms of males.

*E. taylorata* Swett. From the description I had considered it likely that *taylorata* would prove to be a form of *satyrata* Hbn. An examination of the type material showed, however, pretty conclusively that the name should be referred to *gibsonata* Tayl. as a slightly aberrant form with a paler terminal area than usual. The genitalia of the male holotype were somewhat eaten away and a slide was not made; Cassino had made a slide of the female Paratype but it could not be found.

*E. braunata* Swett. A slide made from the Holotype female could not be found but as far as could be told my reference to *russeliata* was correct.

*E. orfordata* Cass. The holotype male is in good condition and a slide (No. 3763) had been made by Cassino of the genitalia. The type series had been placed under *annulata* Hlst. of which *orfordata* was evidently considered a synonym. Judging by the male genitalia of the holotype this procedure seems correct, the depth of the excavation of the ventral plate being similar in both; however, *orfordata* has a deeper and browner ground-color than our Vancouver Is. *annulata* and the name may be held in a racial sense. Most of the specimens in the type series are in very poor shape and it is quite possible that some *olivacea* were mixed in.

*E. joanata* C. & S. The specimen labelled "Holotype, ♂" is a female with long palpi and data "San Diego, Cal. 5.VII.1920" which does not correspond to the data given with the original description; this specimen really belongs to the species I later described as *diegata* and must be discarded as holotype. A slide of the Allotype female (No. 365) could not be found; however from another male which agreed with the Allotype, a slide (No. 1770) had been made and as this corresponded to my slides (from Paratype material of both *joanata* and *balboata* I consider the synonymy I gave (1940, Can. Ent., LXXII, 39) will hold.

*E. vitreotata* Cass. The male Holotype from Colorado is in very poor condition. However by careful comparisons I was able to confirm the opinion expressed (1941, Can. Ent., LXXIII, 192) that the wrongly associated females of *gilata* belonged to *vitreotata*. Females of *gilata*, from which slides had been made, showed the same leg-like type of bursa illustrated in my paper (fig. 7) and matched the *vitreotata* male in other structural details and maculation (as far as could be told). Another similar female, with slide, was masquerading under *joymakeata*.

*E. gilata* Cass. A slide made by me of the male holotype, which was correctly labelled as such, in spite of the foot-note in my article (*op. cit.* p. 193), showed that the genitalia agreed with both Cassino's and my own figures; no change, therefore, need be made in our conception of the species.

*E. mystiata* Cass. Slide made by Cassino (No. 3574) of the male holotype —the slide being marked 'Paratype' in error—agrees with the figure given in my paper (*op. cit.* fig. 3). The female Allotype genitalic slide (No. 3592) also

corresponds. The distinctly bulging front and the short palpi are characteristic of the species.

*E. pinata* Cass. The male holotype has the head of a female *Glaucina* glued on but the slide (No. 3513) agrees with Cassino's figure (as *gilata* but later corrected); a slide of the Allotype female, made by me, also agreed with my figure (fig. 6). In good specimens—of which the type series was very deficient—a dark median area, bordered by pale bands and a very dentate s. t. line are noticeable characters; the palpi are quite long and the front somewhat roundedly bulging.

*Stamnodes pearsalli* Swett. This name was based on a female from Mt. Lowe, Calif. and should probably be transferred to *Stamnoctenis*. In the Cassino Collection only females are placed under the name but the type of maculation is so similar on the underside of secondaries to that of *morrisata* that the generic reference seems fairly safe. *Pearsalli* is a large form with the characteristic bar on the underside of the secondaries decidedly tinged with ruddy; specimens before me from south-central B. C. seem to match.

*Hydriomena henshawi* Swett. A careful examination of the Holotype of this species—a female from 'Nevada' without abdomen and with wings on right side glued on—convinced me that I had consistently misidentified the species, both in the 1917 Revision and in later determinations. The palpi are *decidedly longer* than in the species I had been calling *henshawi* and approach in length those of *shastae*, with which indeed it may be closely associated. I had no material with me for comparison and have found nothing, since my return, in our collection that could be definitely placed under this name. My notes say that the figure given in the revision (Pl. VI, fig. 12) is good and call attention to the curve in the subbasal dark line and the narrowness of band 5. For the species I have been calling *henshawi* the name *expurgata* B. & McD. will apply.

*Xanthorhoe labradorensis* Pack. The type of this species is a female (not a male as stated in the original description) in very poor condition with abdomen lost and only the wings on the right side present. It cannot possibly be referred to *munitata* Hbn. as the outcurve of the t. a. line is not nearly so strong. After a careful study I believe it should be placed under *designata* Hufn. which occurs in this region (we have specimens from Bradore Bay and Hopedale); it matches excellently in maculation but the median area is a duller brown with less of the brighter shades found in specimens from further south. This would agree with Packard's original association, his statement regarding the difference in the ciliation of the antennae being explainable by his error in sex determination.

The species which I formerly (1933, Can. Ent., LXV, 204) regarded as *labradorensis* will now require a new name and I propose for it PACKARDATA n. sp., the Holotype being the male from Bobcaygeon, Ont., mentioned in this article, No. 5584 in the Canadian National Collection.

*Xanthorhoe reclivisata* S. & C. Wrongly placed as race of *ramaria* in the Check List. The genitalia show it to be a good species probably closest to *baffinensis* McD. In color and maculation it can hardly be distinguished from *incursata lagganata* S. & C.

*Xanthorhoe dodata* S. & C. Somewhat larger than the type of *reclivisata* but practically identical in color and pattern. In the genitalia the cluster of spines at the apical end of costa consists of numerous, very long spines, the whole organ being closest to that of *algidata* Moesch.

## ENNOMINAE

*Semiothisa azureata* Cass. The Holotype male may represent a different species from the female Allotype and is hardly a *Macaria* as used in the old sense for species with angled hind wings. The color given in the description

as 'light blue or azure' is quite misleading (Cassino's eye for color in his later descriptions seems to have failed entirely) and to my mind should be designated as 'smoky gray'. The species should be transferred to the old '*Phasiane*' group. According to the genitalia (Slide 3346) the gnathos is rounded apically, the aedeagus long and thin and the harpe a large, triangular projection in the centre of the clasper. I did not recognize the species.

*Semiothisa davisata* Cass. The Holotype male probable represents a different species from the paratypes. These latter all show a discal *ringlet* and are rather contrastingly marked; my reference as a large race of *colorata* was based on a study of one of these but after seeing the Holotype I believe the name will have to be removed from this association. True *davisata* is a rather dull looking thing with the cross-lines thin and faint and the discal spot a thin streak; the t. p. line shows a small angle below costa and is then parallel to outer margin with slight outward bend below fold; no genitalic slide had been made, so I could not place the species.

*Coenocharis utahensis* C. & S. Both this species and the closely allied *tuconensis* C. & S. should be referred to the genus *Glaucina*. The types show a terminal fore tibial spine and the front has the typical raised chitinous ring with central prominence of *Glaucina*. They probably fall close to *eupetheciaria*.

*Nepterotaea polingi* Cass. Quite misplaced in this genus; it shows a terminal fore tibial claw and the front possesses a prominent raised chitinous ring with central tubercle. It should be transferred to *Morina* Grossb. where it fits in excellently.

*Glena quinquelinearia* Pack. After a careful study of the types I believe that the identification of this species made in the B. & McD. Contributions (Vol. III, (4), 240, Pl. XXV, fig. 8) to be incorrect. The two types (♂ and ♀) are much worn but represent a much darker-colored species with strong dark shades before the t. a. line and after the t. p. line on forewing and stronger markings on hind wing. From what I could see of the male genitalia (*in situ*) they approach closer to the figure given of *interpunctata* (*op. cit.*, Pl. XXX, fig. 3) than to that of so-called *quinquelinearia* (fig. 4), especially in the extent of the spined area near apex of clasper. It is possible that *interpunctata* may fall as a synonym but I have no material for comparison nor can I match Packard's type with anything in our collection. Further material will be necessary in order to decide the question.

*Boarmia psilogrammaria* Zell. This name, following a figure and determination by Packard in his Monograph has quite erroneously been placed as a synonym of what is now known as *Pimaphera sparsaria* Wlk. Even a casual reading of Zeller's original description should convince one of the incorrectness of such placement. Zeller particularly mentions a *large fovea* at the base of the forewing and *a hair pencil* on the hind tibia, neither of which are present in *sparsaria*. After a careful checking of the description with specimens from Arkansas and Florida I believe that *psilogrammaria* will fall as a synonym of *pampinaria* Gn. but a check-up of the type in the British Museum will be necessary to confirm this. It might be pointed out that the name *fraudulentaria* Zell., which Zeller proposed rather doubtfully – immediately following the description of *psilogrammaria* – for a specimen which differed in minor particulars from his *psilogrammaria*, has already been placed in this synonymy. I regret I did not search for this type nor for the specimen on which Packard based his conclusions while at Cambridge, but the matter had not at the time been brought to my attention.

*Sicya subviridis* C. & S. Without doubt a synonym of *S. olivata* B. & McD. The type matches the figure given in the 'Contributions' (Vol. III, Pl. I, fig. 10) practically exactly.

## Genus **Pero**

The placement of the numerous so-called species described in this genus by Cassino and Swett has long been a stumbling-block to taxonomists. In consequence considerable time was spent in a careful study of the type material and of the genitalic slides; these latter, as usual with Cassino's slides, were very much flattened and crushed and in consequence difficult of interpretation. As a result of my studies some changes in the arrangement given in the 1938 Check List have been found necessary; the following notes thereon should be of interest.

*Pero dyari* C. & S. Seems correctly placed as a synonym of *honestarius* Wlk. The unique type is a male from St. Petersburg, Fla. but I have matched it practically exactly with a male from Irvington, N. J. (Aug. 10); it seems to represent the lighter brown form, more prevalent in the second brood. Cassino's genitalic figure (as *macdunnoughi,* corrected to *dyari*) is a correct representation of his slide, as far as it goes; the armature of the aedeagus and the shape of the *subscaphium* (an important feature entirely overlooked by Grossbeck in his revision) were difficult to make out owing to the crushed condition but appeared to agree with similar parts in *honestarius.*

*Pero provoensis* C. & S. Based on a single male from Provo Canyon, Utah. The slide of the type could not be studied as it had evidently been misplaced. As far as could be told the name is correctly placed under *giganteus*: in size, coloration, and general appearance it closely resembles specimens of *giganteus* in our long series from Seton Lake, B. C. but it should be noted that the t. p. line (or outer margin of the median dark band) is almost straight, with only traces of excavation or bulge, and the median band is rather narrower than normal. Whether such differences are individual or racial cannot be determined until more topotypical material is available for study; meanwhile the name can remain as placed.

*Pero macdunnoughi* C. & S. Whether this name should be retained as a race of *peplarioides* Hlst. or elevated to specific rank cannot be determined until Hulst's type—or at least topotypical material—from the San Francisco Mts., Ariz. can be studied genitalically. Grossbeck's figure of genitalia was probably based on Californian material and doubtless his 'San Diego' reference included specimens of *macdunnoughi* for which San Diego is the type locality. Cassino's type slide agrees fairly well with Grossbeck's figure of *peplarioides* but the aedeagus is so flattened and overstained that the characteristic angled pieces of chitin at apex could not be located; however, there is a very good character to be noted in the subscaphium which should be helpful in tying down the name; this part is very large and shows a strong, pointed, ventral projection below its apex, somewhat resembling a bird's beak; below this is another rounded shelf-like projection, extending almost as far outwardly as the 'beak.' In coloration *macdunnoughi* most resembles *giganteus* with its mouse-gray shades, deepening into almost black in the outer portion of the median band; it is, however, considerably smaller and the black dot on outer margin above vein 2 much reduced; a slight ruddy tinge is present on costa beyond the angle of the t. a. line. Grossbeck's figure No. 4 might readily have been made from a specimen of *macdunnoughi.*

*Pero splendorata* C. & S. The name is based on a strongly marked *behrensarius* from Modoc Co., Calif. and seems hardly worthy of racial separation. The male antennae are non-serrate and the genitalic slide matches Grossbeck's figure and certain of my slides of *behrensarius* quite well.

*Pero modocata* C. & S. The holotype is a female and not a male as stated in the original description although the rest of the data given correspond with that on the label; I did not find other specimens nor genitalic slides. The holotype was very well matched by a male specimen from the Charleston Mts., Nevada in our collection. This specimen shows non-serrate antennae and has

the forewing maculation much as in *behrensarius* but without any of the brown shading, the basal and median areas being strongly peppered with blackish; in contrast the pale subterminal area, with slight ruddy tinge, stands out strongly, the terminal area being again quite dark. In the genitalia the aedeagus is furnished with a small apical chitinous plate to which is attached a small spine; the subscaphium is rather large, the upper section hollowed out and rounded with moderate ventral ridge, the lower portion rather broad and flat.

*Pero blackmorei* C. & S. This can hardly be considered a race of *occidentalis* Hlst. as the male antennae are not sufficiently serrate. The name was based on a male specimen from Mt. Lowe, Calif. and I could not match this with any of my material; I noted, however, that Cassino's genitalic drawing was accurate as far as it went and that the species on the whole was reminiscent of *modocata* with somewhat browner tinges in the median band and a stronger bulge of the t. p. line above the inner margin. Until topotypical material can be secured for examination the name had better be placed as a specific unit next to *modocata.*

*Pero packardi* C. & S. This name, as well as *patriciata* C. & S., has been listed as a race of *colorado* Grossb. Unfortunately there seems to have been some mix-up by Grossbeck in his series of *colorado.* The type was stated to be in Dr. Barnes' Collection without further indication of locality, etc., other than the general statement that the material came from Durango & Glenwood Spgs., Colo. and also from Yellowstone Park. In this collection there are, according to information furnished by Mr. H. Capps, only 'cotypes' and it is likely that Grossbeck's whole type series was so-labelled. One of these specimens, a male, was figured in the B. & McD. 'Contributions' (Vol. 1 (4), Pl. XXI, fig. 14) and I propose to make this the lectoholotype. It does not agree at all well with the specimen figured by Grossbeck (Pl. 13, fig. 8) as *colorado,* nor do the genitalia agree with the figure given (Pl. 16, fig. 8), concerning which no information was recorded. Mr. Capps who has kindly looked into the matter at my request, informs me that he does not "know from what source the figure (Pl. 16, fig. 8) was drawn but it certainly does not agree with his (Grossbeck's) cotype slides, one of which would be regarded as the type since he stated that the type was in the Barnes Collection. On the basis of similarity of genitalia *colorado* should go next to *modestus.*"

With regard to *packardi* I have matched the type male from Wallace, Idaho with another topotypical specimen; the serrate antennae throw it into the *occidentalis* group and until further detailed studies can be made it had better be placed next to this species.

*Pero patriciata* C. & S. The single male type from Kenosha Pass, Colo. is a weird-looking thing with considerable ruddy suffusion along the margin of the hind wing before anal angle; I have seen nothing to match it. As the antennae are serrate, as in *occidentalis,* it can, for the present, follow *packardi* in placement.

*Pero barnesi* C. & S. The genitalic slide made from the holotype of this species from Salem, Mass. does not match the figure given by Cassino at all and I can only presuppose some mix-up in the labelling of the drawing as the slide appears to be authentic. According to both specimen and slide *barnesi* is very close to *marmoratus* with the same type of long, thin aedeagus found in no other of our Peros. There are, however, certain small differences in both genitalia and maculation which incline me to keep the two names separated. Among other things, *barnesi* shows considerably less marbling on the subterminal area of primaries, the dark patch which fills out the excavation of the t. p. line in *marmoratus* being practically lacking. There is a possibility that this is *hubneraria* Gn. (*ancetaria* Hbn.) as Hubner's figure approaches closely to several specimens of *barnesi* before me. The species is probably not rare in the Atlantic and Middle States but has been confused with *morrisonarius.*

# CONDITIONS GOVERNING THE DISTRIBUTION OF INSECTS IN THE FREE ATMOSPHERE*

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## PART IV: DISTRIBUTIVE PROCESSES OF ECONOMIC SIGNIFICANCE

### *Introduction*

The economic entomologist is concerned with the eradication or control of insect infestations, or with the restriction of spread of pest-species. In the course of such work, he is often confronted with the appearance of new infestations in cleared or virgin areas. These infiltrations from other source regions originate, in part, from the gradual extensions of other foci by flights or migratory movements, and, also from the intervention of air currents.

It has been definitely established that a considerable population of current-transported insects exists at higher altitudes. In previous sections of this paper, it has been shown that many insects may be subjected to the rigorous environment of the upper air, and yet return to earth with no apparent loss of vigor or vitality. Air currents as means of distribution for these air-borne insects also have been discussed. Now, it may be useful to evaluate the relative economic significance of the various processes acting to distribute insects.

### *Spheres of Influence of the distributive Processes*

Previously, air currents have been classified as vertical or horizontal, on the basis of their direction of flow. To this may be added the distinction between short and long-range currents, on the basis of their powers of distribution. Within their ranges, all currents may act to extend a specific insect flight-range abnormally, by assisting the deliberate flight of the insect; or, they may literally carry the insect, winged or wingless, from one area to another.

During the previous discussion of horizontal and vertical currents, it was stated that the horizontal wind-flow was of importance to insect distribution only within zones of temperature favorable for insect activity. This statement applied to both vertical and horizontal distribution by the action of wind alone (i. e., minus eddy motion). In other words, deliberate flight plus purely horizontal wind may abnormally extend a flight-range, but passive transport by purely horizontal wind cannot result in any gain of distance.

This requirement of a deliberate contribution on the part of a winged insect limits the sphere of wind influence to the lower, warmer levels of the atmosphere. The sphere is restricted further by the requirements of apterous, or otherwise passive forms. For their support and transport, such passive forms require the presence of a vertical eddy in the wind. Thus, in such cases, the wind-sphere is limited to the friction layer of the lower atmosphere (i. e., normally 0-2000 or 3000 ft.).

The actual sphere of wind influence is shown by existing aircraft-collection data. These indicate that the sphere is quite definitely limited to the friction layer. Such data also indicate that the majority of the aerial population is present within this region. The wind-sphere, then, may be defined as one of low altitude, often possessing extensive surface area, and containing a considerable population. As such, it encompasses the only distribution processes which may be designated as long-range.

The erroneous idea that wind velocity increasing with height will lift insects higher and carry them farther demands, if pushed to its ultimate conclusion, a population which is at least evenly distributed throughout the whole vertical collection-range. On this logic, the population actually should increase with altitude, since the wind strengthens with height. This view cannot explain

* This paper is the last of a series appearing in succeeding numbers of the *Canadian Entomologist.*

why the insect population is denser in the lower levels, thinning rapidly beyond the top of the friction layer.

In Part II, it was suggested that the plankton zone of other authors be subdivided into "active" and "inert" zones, by virtue of the condition of the insect inhabitants brought about by high or low temperatures. The upper limit of the active zone was set at about 2-2.5 km. This zone was said to contain all individuals liable to extensive horizontal distribution.

It will be seen that there is some overlapping of the wind-sphere and the active plankton zone. To avoid possible confusion, it should be pointed out that much of the lower part of the plankton zone lies within the friction layer. Hence, the friction layer winds are responsible for all the great distributions within this lower portion. It seems to be a matter of observation that these winds are also responsible for most long-distance distributions. The remaining portion of the active plankton zone, above the friction layer, contains winds which seem to be potential, rather than actual long-distance distribution agents.

It has been shown that purely vertical currents may carry insects to very high altitudes, but the short duration of the processes, their small individual areas, and their scattered surface distribution bar them from effective long-range transport. This is especially true when low temperature exists, and turbulent wind-components are absent outside the convective zones, as is the case at high altitudes. The sphere of influence of these short-range, purely vertical currents, then, may be extended to very high altitudes, but must be restricted in surface area to the diameter of a single convective current, or to the area covered by a small family of such currents.

The restriction of population due to convection to the thermal cores may seem rather arbitrary. Proof of this contention demands that insects at high, cold altitudes be found concentrated in isolated groups, with relatively barren areas between such groups. Aircraft collecting, cutting through all such negative and positive zones on a level, then should indicate a relatively sparse population for the whole level. The fact that aircraft-collection data actually do indicate a considerable reduction in the overall population above the friction zone, and at higher levels where it is too cold for active flight, supports this contention.

### *Factors necessary for significant Distribution*

In the atmosphere, wind is acting at low altitudes, distributing insects over short or long distances. It acts upon a large, mixed population near the surface. Convection is responsible for regrouping of a smaller, aerially-specialized population, which is carried to higher altitudes, but is returned to the surface within a relatively short distance of its starting point. The question arises as to which process is most important economically: low-altitude, long-range distribution; low-altitude, short-range distribution; or, high-altitude, short-range distribution.

The answer to this question must vary somewhat with the species of insect involved. For a given pest-species, the answer is dependent partly upon where the species considered falls in the zonal classification of insects in the atmosphere. Correlation of the proper stage of the insect life-cycle with the weather-state necessary for successful distribution also is important, if successful distribution is taken to mean successful establishment in a new surface area.

The atmosphere has been divided into a "terrestrial" and a "plankton" zone of insect population-types. Both of these zones contain pest-species. The type terrestrial-zone insect is considered to be a strong flier, unaffected by currents of normal magnitude, although it may be assisted by such currents. Hence, under ordinary circumstances, the flight-range of such an insect would be almost wholly that covered by deliberate flights at a fairly low altitude.

Plankton-zone insects are considered to be weak fliers, small-bodied insects of large wing-area, or small apterous forms. To fit its definition, winged plankton must, of necessity, be affected by all types of air currents. Hence, a winged form must be influenced by both wind and convection, and be liable to any range of distribution noted above, at either high or low altitude. Apterous forms are susceptible to distribution by processes involving vertical currents.

The successful distribution of an insect presents problems analogous to those of logistics. In the final analysis, it demands that the right stage of the species must arrive in the right place. For the successful establishment of most insect species, the correct stage may be: a gravid female; sufficient males and females to ensure mating; or not one, but many, larvae.

Obviously, in most cases, the most difficult part of the whole problem lies in achieving the delivery of the air-borne stage to the right place. Any insect occupies what is essentially a micro-habitat, and the acquisition of new quarters by a drifting form is rendered no less difficult because the habitat may be any part of an extensive acreage, if that acreage is a small part of a surface several hundred or thousand square miles in extent.

The air may be considered very like the sea in regard to the chances for successful re-establishment which it offers to its drifting population. Despite the fact that there is a sizeable aerial population of insects, it is clear that a given successful distribution must overcome many hazards. The chances of a single insect alighting in a suitable habitat are not good. If this insect must be capable of carrying on the race, the outlook is even darker.

It is apparent that a fairly steady stream of the required stage, preferably the adult, is necessary for the establishment of a new focus from the air. Numbers are required, so that the necessary amount may be dropped in the correct place. This calls for a fixed circulation over a goodly time-interval. The farther the species must travel overland, the less likelihood there is for the weather-state to prevail long enough to supply this continuous stream for the required time. Weather is anything but static, and when a regional circulation changes, it may not be restored in exactly the same way for some weeks or months. During this lapse of time, the correct stage of the life-cycle may have passed.

The long-range distribution by winds may provide many interesting or spectacular examples of species collected hundreds of miles from their points of origin, but the process cannot be of much value for successful distribution or for survival. In this connection, authors reporting cases of extreme distribution usually mention finding the insects in extremely inhospitable surroundings, but evidently assume that this constitutes an exception to the normal habitat-linking efficiency of long-range distribution by winds. Such an assumption does not necessarily follow. Unless the weather conditions linking two distant habitats coincide with a sizeable insect swarm or migration, no economically significant distribution will be attained. This combination is difficult to achieve. Even the famous trans-mountain grasshopper migrations "aided" by up-slope winds seem to have a distressing tendency to end on a snowfield or glacier, which cool the insects below flight-temperature with rather detrimental results.

Many authors have drawn attention to oceanic islands populated by wind. As a matter of fact, it would seem that the population of such islands by long-range wind distribution is really easier to attain than are far shorter distributions overland. Losses of individuals must be great, but it must be remembered that there are very steady and durable circulation regions, such as the trade-wind belts, over ocean surfaces.

*Processes aiding successful Distribution*

If steadiness of direction, and a lengthy duration are demanded of a process acting for successful distribution, the question arises as to what pro-

cesses supply such a quality. It has already been shown that, on the whole, long-range distribution has little chance for success. If the oceanic winds are disregarded, the better processes are, with one notable exception, of fairly short range. The single exception is the occasional action of a region of high barometric pressure, and the effect of this on wind direction and duration.

High pressure areas sometimes become relatively stationary over a region for many days at a time. In such cases, in certain parts of the high, the layer of turbulence cloud produced (i. e., cloud-streets, etc.), or the equivalent clear, windy conditions will maintain a more or less definite direction of circulation throughout the stationary period. Such conditions may occur in spring or autumn, and may well act to distribute numbers of a given species for hundreds of miles along a fixed track, thus ensuring the establishment of the species in any suitable habitat along the wind-path. This is the best process for successful long-range distribution.

Other processes aiding successful distribution may be considered to be purely local in character. These local effects may take the form of winds of definite direction, with or without eddy components, or of convective currents. The local processes usually are caused by topography, and often have a diurnal variation. In this category may be included valley winds, trans-valley turbulence or convection, lake or sea-shore breezes, slope winds, etc.

It is processes such as these, of short range, but of fixed direction and frequent occurrence, which must be held responsible for the most economically significant distributions of insects. Day after day, insects may be carried along the same route, possibly over natural barriers, until sufficient numbers have been transported to overcome the limitations of aerial distribution. Although the classification of these processes indicates a fairly specialized occurrence through topographical restrictions, it is safe to say that no area may be considered to be free of such processes. Most observers will recall a local peculiarity of the wind or air currents of their own sections.

Cross-valley turbulence is of particular interest in regard to insect distribution. If a river-valley is so situated that one slope receives insolation during the morning, while the opposite side receives afternoon insolation, turbulent currents are produced which may develop a cross-valley direction, even though the wind-direction is along the valley. It will be seen that such currents can bring about an inter-change of insects from opposite sides of the valley, including forms which normally might be incapable of crossing the river. A persistent wind-direction added to the turbulent currents may result in the transport of species, not only across the valley, but for some distance farther along it. The international disputes arising from sulphur dioxide crop fumigations from the Trail Smelter, British Columbia, provide an illustration of the effects of cross-valley currents.

It will be seen that the most significant distributions of insects are the results of atmospheric currents restricted to a few square miles in surface area. These short-range processes may be high or low-altitude processes. So many factors are required for successful distribution that long-range distribution by winds may ordinarily be neglected by the economic entomologist. While short-range processes may effect a successful redistribution in a relatively short-period of days or weeks, long-range distribution requires a period of several years to be effective under normal circumstances, and consequently is of little practical concern to the economic entomologist. What regional winds may accomplish in several years, aircraft or other mechanical transport can easily complete in a few hours or days. Thus, the enforcement of quarantines and inspections is of greater importance than any correlation of control measures with regional weather forecasts.

*Short-range Processes and Insect Control*

The so-called short-range processes may produce distributions which are economically significant. If such a distribution is suspected in a pest-control problem, recognition of the factors involved may make it possible to take steps to counteract the effects of the processes, or even to use them to advantage in the control measures.

It should be possible for the entomologist to determine the stage of the species which is susceptible to aerial distribution, by a consideration of the habits of each stage in the life history. The stage of the species will also indicate whether it is a terrestrial type, and so dependent chiefly upon deliberate flight; or whether it is a plankton type, and so dependent upon current drift. It is, of course, possible for a species to exhibit plankton characteristics at one period, and terrestrial characteristics at another period. The most important period must be distinguished in such cases.

The entomologist should also be able to determine any local topographical effects, by observation and by consultation with the local meteorological authorities. Pilots of aircraft, also, often may be of assistance through their knowledge of any local peculiarities in the current-structure aloft.

Once the air-current pattern has been determined in a general way, infiltrations of the species may be traced to likely source regions by field-survey methods. If the source foci can be eradicated by ordinary control methods, then control of the situation is primarily a matter for the entomologist. If the source foci cannot be dealt with directly, as is often the case, then the meteorologist may render good service by advising when dangerous aerial conditions may be expected. This may be either a matter of determining the diurnal fluctuation of a recurring process, or of forecasting the arrival of a general weather situation which produces the known local effect. With this information, the entomologist is then in a position to take steps to apply suitable chemical, cultural or mechanical control measures at a time coinciding with the dangerous aerial conditions.

*Summary*

The distribution of insects by wind in the atmosphere occurs within the lower layers. Such distribution may be over a short or long range.

Convection may carry insects to high altitudes, but distributes them over relatively short ranges at the surface.

To establish a new insect colony of economic significance, a distributive process must combine the properties of steadiness in direction and lengthy duration. In this regard, long-distance distribution by wind usually may be neglected since it is an unsteady phenomenon, only occasionally delivering a few individuals of a given species to a suitable habitat.

Short-range, high or low-altitude processes produced by local topography are of most significance economically. These processes are more or less fixed in direction, and recurrent at short intervals. Thus, they may be responsible for the infiltration of a species in a relatively short time.

It should be possible for entomologists to utilize the presence of such weather factors in planning the control of pest-species. It may or may not be necessary to call in local meteorologists for weather information.

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REFERENCES

Bristowe, W. S. 1929. The distribution and dispersal of spiders.. Proc. Zool. Soc. 43:633-657.
Dean, R. S. and Swain, R. E. 1944. Report submitted to the Trail Smelter Arbitral Tribunal. U. S. Bureau of Mines, Bull. 453:304 pp.
Dorst, H. E. and Davis, E. W. 1937. Tracing long-distance movements of beet leafhoppers in the desert. Jour. Econ. Ent. 30:948-954.
Elton, C. S. 1925. The dispersal of insects to Spitzbergen. Trans. Ent. Soc. London, 1925: 289-299.
Felt, E. P. 1926. Dispersal of butterflies and other insects. Nature, 117:365-368.
Gaines, J. C. and Ewing, K. P. 1938. The relation of wind currents, as indicated by balloon drifts, to cotton flea hopper dispersal. Jour. Econ. Ent. 31:674-676.
Gordon, W. M. and Page, R. Z. 1943. The effect of winds of hurricane velocity on mosquito trapping results at Corpus Christi, Tex. Ent. News, 54:251-252.
Hardy, A. C. and Milne, P. S. 1937. Insect drift over the North Sea. Nature, 139:510-511.

# THE WORKER CASTE OF *HARPAGOXENUS CANADENSIS* SMITH (FORMICIDAE).

BY ROBERT E. GREGG,

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During the summers of 1941 and 1942, with the help of students, I collected in the vicinity of Duluth, Minnesota, some individuals of a species of ant recently described by Dr. M. R. Smith (1939), from Quebec, Canada. The original account of *Harpagoxenus canadensis* was based on the queen caste, an intermediate ergatoid female type, and a simple ergatoid female type, representing 12 specimens in all. No workers apparently were known, but since then this caste has been collected from several localities, and the material from Duluth consists of workers, ergatoids, and one queen. Dr. Smith has kindly confirmed the identity of the specimens, and has suggested that the worker caste be described and figured. Accordingly, I append the diagnosis of this insect, together with notes on additional localities* for the species and a few ecological observations.

## **Harpagoxenus canadensis** Smith

*Worker.*—Length 3.5-4.0 mm.

Head slightly longer than wide, sides subparallel, only slightly convergent anteriorly; occipital corners rounded and posterior border faintly concave. Clypeus with two, blunt carinae which do not form projecting teeth; area between them depressed and the anterior border broadly emarginate; posterior margin extending deeply between the frontal carinae. Frontal carinae distinct and diverging gradually from anterior to posterior extremities, continuing almost to the occipital angles and forming the medial borders of conspicuous antennal scrobes. The lateral boundaries of these depressions are less distinctly marked by ridges which pass just medial to the eyes, and the antennae in repose are folded into the scrobes. Eyes of medium size, placed slightly anterior to a point mid-way between the mandibular fossae and the posterior angles of the head; distance from fossa to border of eye equal to 1 2/3 the diameter of the eye. Antennae 11-segmented, robust, the last three segments incrassated and forming an indistinct club; last segment slightly larger than the two penulti-

* Dr. M. R. Smith of the Bureau of Entomology and Plant Quarantine in Washington, D. C., has kindly supplied most of this information, and Mr. W. F. Buren has given me the record of the species, which he has from Minnesota. Dr. Smith has also read the manuscript and made certain suggestions.

mates. Scape broad, flattened, and curved at the base, reaching only about 2/3 the distance to the posterior angles of the head. Mandibles broad and abruptly curved so that the basal borders are angled; apical edges concave and without teeth. Maxillary palpi 5-segmented.

Thorax narrower than the head, being widest at the rounded humeral angles; in profile evenly rounded and low, passing into a shallow but distinct mesoëpinotal impression. Epinotum with subequal base and declivity and well developed spines which are nearly horizontal, but project slightly upward

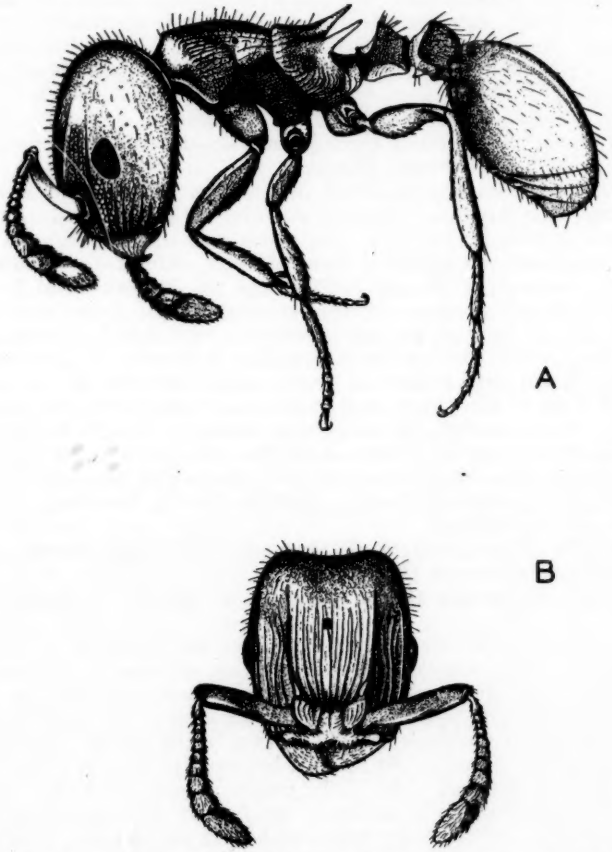


Fig. 1. A, Worker of *Harpagoxenus canadensis* Smith; B, head of same.

and outward from their bases. Petiole much narrower than postpetiole (the latter 1/3 wider); node tapered to a thin but truncated superior border, and the sides converging dorsally when viewed from behind; anterior slope steep and peduncle very short; posterior slope somewhat lower; antero-lateral corners tuberculate, sides carinate, and a pronounced ventral tooth present at the anterior end. Postpetiole globose in profile and trapezoidal from above. Gaster of the usual shape, anterior face flattened to receive the postpetiole, and the antero-lateral margins angled.

Sculpture: Front of head with straight rugae paralleling the frontal carinae and continuing as finer striations onto the clypeus; antennal scrobes punctate and the genae punctato-rugulose; occipital angles and centre

of gula glabrous. Thoracic dorsum with fine, longitudinal rugae interspersed with small punctures; pleurae of the same texture except that the punctation is more evident. Epinotal base and sides punctato-rugulose; declivity transversely striated. Petiole coarsely, and postpetiole finely punctate. Gaster smooth and shining.

Pilosity: Hairs abundant and clavate on the upper surface of the head, thorax, petiole, postpetiole, and gaster, and arranged in transverse rows at the posterior margins of the abdominal segments; present though less numerous on the gula, pleurae, coxae, femora, and tibiae. Pubescence sparse and most easily detected on the head, gaster, and legs; long and closely appressed.

Color: Head and gaster dark brown, thorax lighter; legs and mandibles yellowish to yellowish brown; eyes and cutting edges of mandibles black.

*Host.—Leptothorax acervorum* subsp. *canadensis* Provancher.

*Morphotype.*—Present in the author s collection.

*Additional specimens of the worker caste.*—In the author's collection and deposited at the U. S. National Museum.

Described from one specimen in a colony of 16 adult individuals (10 workers and 6 ergatoids). Twenty-two winged, female pupae and 15 male pupae were present in the same nest which was collected from a rotting log (stage 2) in a tamarack-spruce bog near Duluth, Minnesota. Additional specimens were obtained by Messrs. A. Wiljamaa, R. Freeman, and J. Zygmanski; one of these records is from a maple-basswood forest. In no case was a large colony found, and most of the collections were represented by isolated ants. In the nest from which the worker is described a number of individuals of the host species of ant were present, and were sufficiently like the slave-maker that the mixed state of the colony was not noticed until after the return to the laboratory. Unfortunately, no males were obtained, though, as indicated, male pupae were secured and no doubt would have emerged in a few days.

Localities from which *H. canadensis* is known to date are as follows:

Quebec, Province of Quebec, Canada (Jos. I. Beaulne)—Type locality. (3 queens and 9 ergatoids).

Kentville, Nova Scotia (R. P. Gorham). (1 winged female).

Ponsford, Minnesota (W. F. Buren).

Duluth, Minnesota (R. E. Gregg). (1 queen, 17 ergatoids, and 13 workers).

The worker of *H. canadensis* differs from the worker of *H. americanus* in that the head is larger, rugose instead of punctate, subopaque, and lacks a median frontal ridge. The antennal scrobe is slightly shallower, and the masticatory border of the mandible forms a smooth cutting edge rather than being dentate. The anterior clypeal margin is broadly concave in the middle instead of sinuate, and the posterior clypeal margin extends between the frontal carinae as a more quadrate (or less rounded) lobe. The petiole is wider and the node is entire whereas in *americanus* it is distinctly notched in the specimens before me. Epinotal spines are a little longer and straighter in *canadensis*. Thoracic dorsum is rugose, while in *americanus* it is punctate with only the epinotum rugose in the latter. Color of thorax is noticeably lighter brown, and even the head and petiole are a shade lighter in *canadensis*.

## LITERATURE CITED

Smith, M. R. The North American ants of the genus *Harpagoxenus* Forel, with the description of a new species. Proc. Ent. Soc. Wash. 41:165-172, 2 fig., 1939.

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